

ZJER

ZIMBABWE JOURNAL OF EDUCATIONAL RESEARCH

Volume 26 Number 2
July 2014



UNIVERSITY OF ZIMBABWE

Volume 26, Number 2, July 2014
ISSN 1013-3445

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Cultivating Pedagogical Content Knowledge (PCK) in In-Service Science Teachers: Addressing Deficiencies of 'Teaching as Taught'

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Abstract

The infrastructural educational landscape in Botswana has grown at a tremendous pace in the past two decades. However, this growth has not been paralleled by similar growth in the performance of students in the same school system. On the converse, performance seems to have declined with the increased infrastructural development almost at a directly proportional fashion. A self-study and exploratory case study methods were used in the research. Impact on chemistry in-service teachers' conceptions of chemistry was looked into. Classroom interactions at the secondary school level showed that most of the teaching activities used in the classrooms have not changed from what they were some decades ago. In the area of chemistry education, for example, teaching has become simply a matter of keeping up with the tradition of teaching-as-taught. Using the topic atomic theory, this paper attempts to show that the tradition of teaching-as-taught can be challenged and changed by equipping teachers with proper armour so as to be able to face the challenges in their classrooms. It is argued that teachers resort to teaching as taught when they run out of ideas on how to tackle difficult and abstract topics so common in chemistry, and that given appropriate arsenal, they can develop enough confidence to present materials to students in very innovative ways. Recommendations are given in the form of questions that should be interrogated further to seek answers to the problems.

Introduction

Pedagogical content knowledge (PCK) has been defined as a way of understanding the complexities of the relationship between teaching and content through the use of specific teaching approaches (Loughran, Milroy, Berry, Gunstone & Mulhall, 2001). PCK has reference to particular topics and how they are taught, is reflected in the teachers'

understanding of what concepts are to be taught, the selection of appropriate instructional materials for students as well as the most appropriate strategies (Faikhamta & Clarke, 2013) and as such differs from subject matter knowledge (SMK) (van Driel, De Jong & Verloop, 2002).

Debates rage on how to best prepare quality science teachers (Kind, 2009). On one hand is the view that teachers need to be given rigorous training on their subject content at college, on the other is the thinking that an equivalence of college second year subject content is enough for a teacher at high school (Personal communication, Chemistry Department Meeting, University of Botswana, 16/10/2013).

As a teacher educator, the author has observed countless lessons presented by student teachers during teaching practice both in Botswana and in the United States of America. Since PCK is not taught in methods courses *per se*, and possibly also because of its tacit nature (Kind, 2009), student teachers bring a lot of SMK to their teaching practice sites, only to realize that it takes much more than content knowledge to deliver a successful lesson. When all else fail, the tendency is for the student teacher to revert to what I call *teaching-as-taught*; a practice where teachers completely disregard all conventional methods course drills and do what they remember their content teachers doing when they were taught the same topic in school.

This paper therefore, aware of the illusive nature of PCK due to its tacit nature, is hinged on the premise that positive deposits can be made into the student teachers' PCK accounts during their methods courses by ensuring that problematic concepts are dealt with to enable them to fully understand. This full and comprehensive understanding of the SMK would help the students teachers develop a deeper understanding of the concepts and to be in a position to *present them in more than one way*. Trained this way, it is hoped that the student teachers would not succumb to the urge to teach as taught when their students do not understand concepts but be persuaded to dig deep into the PCK bag to reach as many students as possible.

Background to the study

Student performances at the Junior Certificate (JC) and Botswana General Certificate Secondary Education (BGCSE) levels in 2014 were dismal. For example, according to the Botswana Examinations Council (BEC) only 24.27% of the total students who sat for the BGCSE examination obtained 5Cs or better in their overall results. For chemistry, only 4.87% obtained grade C or better (BEC, 2014). A number of factors lead to this dismal performance by students. These range from the mass production of teachers and/or students due to massive infrastructural expansions across the country, the generally disgruntled teaching force, to the 2010 national strike that left students without teachers for extended periods of time. Botswana has also performed dismally as a country in the international scale as in the last TIMSS report (TIMSS, 2007).

A lot has been happening in the Botswana educational landscape that does not seem to settle well with the teaching fraternity. The students performing below expectation at the lower level seem to also face challenges at tertiary levels. This is so rife that the Chemistry Department at the University of Botswana decided to look into the cause of the poor performance by students in the Department (Personal communication, Department of Chemistry Quality Assurance Team Meeting, University of Botswana, 16/10/2013).

For a school system such as Botswana's to perform well, many players would have to be involved. These players have very important and interconnected roles such that if one group does not perform its part, all efforts by the other concerned parties would be futile. Below are the described critical roles of each of these groups and how each group fits into the equation.

In-service teacher education

The training of teachers is crucial for the development of any school system. In the case of Botswana, where the system is centrally managed by government through the Ministry of Education and Skills Development, there is usually a uniform spread of teachers by both ability and experience across the schools system. To maintain this spread, experienced teachers, as per need, are sent out for further

studies. These teachers for the most part are Diploma holders sent to read for a Bachelor's degree. On occasion however, teachers with degrees are also in-serviced to do Master's degrees in different educational fields.

The Diploma in-service teachers are of interest for a number of reasons. They are mature age wise and would have been teaching lower level science for a minimum of ten years at the junior secondary level. They are a product of various colleges of education in the country, with a few exceptions of those who trained for their teacher education Diploma with the University of Botswana. The level of science done at the colleges of education has been a subject of contention for a number of years. It is believed that the students are not grounded enough in science concepts and therefore have lower SMK.

Adult educators use what they call *professional artistry*, being the level of competency that allows for unprecedented flexibility in going about their professional roles (Brockett, 1991), to push an agenda for change in the implementation of meaningful adult education interventions. Loucks-Horsley et al (1998) describe the same concept as *immersion in inquiry into science or mathematics* based on the assumptions that teachers, in-service teachers in particular, during training, should be engaged in similar learning situations as they would encounter in their own classrooms. In-service teachers are therefore opportune candidates for interventions that tap into deep rooted PCK cultivation.

Educational reform

Resulting from the recommendations of Revised National Policy on Education (KNPE) of 1994 (Republic of Botswana, 1994), the government of Botswana embarked on an agenda to reform the educational system. Junior and senior secondary schools were built as part of the development of schools physical infrastructure. Existing senior schools were expanded and enrolment transition from one level of education to the next increased dramatically. For example, transition from primary to junior school neared 100% and from junior to senior secondary was the highest ever at near 50% (Suping, 2004; Vlaadingerbroek, 2001). These changes were aimed at overhauling the educational system and producing what Tabulawa (2009) calls a self-programmable learner

The changes alluded to earlier, gave the country a false sense of hope in the products of the system under development. On the contrary though, performance declined despite all the investments in infrastructure and human resource development. Questions arose as to how such a well equipped education system as Botswana's, comparatively, could be performing worse than other systems on the African continent that are operating on less than half of what the Botswana system was using. It was argued that the small population of the country, coupled with the massive resources at the disposal of the school system should render an effective and efficient school system functioning and operating like a well-oiled machine.

Discontentment with the performance of the Botswana school system as a whole is not new. The first Commission on Education in Botswana of 1977 concluded:

Education may have grown much, but it has changed little ... qualitative standards are low ... education generally has failed to satisfy the hopes of Botswana (Republic of Botswana, 1977, p. 1).

These hard realities were against a backdrop of massive expansions both infrastructural and enrolment wise. Kahn (1990) makes reference to enrolments at both primary and secondary schools increasing by up to 45%.

Tabulawa (2007) quips that the nebulous concepts of effectiveness and efficiency come about as a result of globalization drives, as the global puts dictates on the local. No wonder Vlaadingerbroek (2001, p.315) commented about Botswana that "... system is currently undergoing reform with the view to improving the efficiency of the nexus between schooling and the 'world of work'". Local responses sometimes come with strain to the available resources.

It could be argued that changes undergone by the Botswana schools system were as a direct consequence of the influence of globalization on the nation (See Tabulawa, 2007, 2009). Polelo (2009) claims that the expansions at the primary in the 1980s and secondary in the 1990s were at the sacrifice of the higher education sector, which were to produce

teaching personnel for the lower expanding levels. The massive expansions at lower level did not seem to be in congruence with the needs at higher education level.

Teacher competency – PCK

A lot has been written about PCK (Faikhamta & Clarke, 2013; Kind, 2009). Different beliefs and views on PCK exist. Faikhamta and Clarke (2013) contemplated the ideas of enhancing PCK in student teachers, supporting its development as well as developing PCK in the teacher educators themselves as they interact with their student teachers. The import of this view is that well calculated moves can be incorporated into methods courses with a view to developing student teachers' PCKs in certain concepts that are known to be problematic. Koosimile and Suping (2011) held the view that both pre and in-service teachers are very critical change agents in the contemporary context of globalization in education and that as change agents, the teachers need to be empowered. One such empowerment strategy would be to teach targeting development of appropriate PCKs on topics being covered in class.

The “focused pre-service training that can help them [pre-service teachers] to prosper and grow in influence in their profession” alluded to by Koosimile and Suping (2011, p.459) could also be extended to in-service teachers. In-service teachers are better placed due to their classroom experiences that they tap into as they are being taught and identify with some of the challenges that they faced in the field.

This paper therefore reports on attempts by the author to teach in-service chemistry teachers using a pedagogical technique that was aimed at aiding the teachers develop appropriate knowledge that enriches their pedagogy, hence fast tracking the development of their PCK in the topic taught. The premise on which this attempt is made is that teachers resort to ineffective methods of teaching, including teaching as they were taught when they feel overwhelmed by what they have to present to their students. Whilst teachers would never want to admit it, there are areas of study that they have to present to students that they [teachers] are just not comfortable with. They simply do not know enough about the topic to present it comfortably to the students.

Why the atomic theory?

The atomic theory is one such topic that is covered in the high school syllabus that teachers are not very comfortable with teaching (Garanja, Musasia, Wanyonyi & Twoli, 2012). The reason given being the abstract nature of the concepts such as orbitals that teachers have to teach. Part of the problem also stems from the difficulty by students to differentiate among macroscopic, microscopic and symbolic as ways of representation (Garanja et al, 2012).

In the BGCSE syllabus, the treatment of the atomic structure is shallow; the bulk of the grounding on the atomic theory is covered at college level chemistry. In 2003 the author observed a student teacher in Columbus, Ohio, who had to cover orbitals as part of the Schrödinger equations. A mammoth task given that the student teacher had to treat the equations qualitatively and was only in his second quarter of three years of teaching experience, having had a full ten week previously of teaching placement experience in a middle school. The student struggled to teach the concept.

Whether the Schrödinger equations are treated at the senior school level or put off to college boils down to the fact that the students still have to have an understanding of what they are or represent so as to be able to get grounding on electronic configuration and many other concepts in the chemistry syllabus. They are crucial to understanding the atomic theory chemistry.

Methodological considerations

Events of the teaching episode in Columbus, Ohio in 2003 alluded to earlier, influenced the quest to look into ways in which teachers could be helped to deal with problem topics in chemistry. Beginning 2005 to 2010 the researcher taught chemistry courses to in-service teachers with experiences in teaching science at the junior school levels in excess of 10 years. Each cohort was around 15 students or less. These students spent one year doing chemistry in the Department of Mathematics and Science Education (DMSE). Ordinarily, all science content courses are done at the Faculty of Science. For these students however, the courses were designed to be bridging courses for two

reasons. The students were out of the classroom for at least ten years and so it was felt they needed to be eased into the classroom again. Secondly, a large portion of the students were science graduates from the colleges of education. There is a strong belief that the science done at the colleges is not robust enough. Starting off at the DMSE, it was felt, would give them the necessary cushion of being taught by teacher educators with very strong content as well.

Two courses were offered in chemistry along with other subjects such as biology, physics and mathematics each semester and the researcher offered one of the two chemistry courses in each of the semesters. In the first semester the topics covered in the course offered by the researcher were atomic theory, matter, the gaseous state and the periodic table. In the second semester the topics were properties of solution, gaseous and heterogeneous equilibria, acid-base equilibria and solubility equilibria. Of all the topics, atomic theory seemed the most abstract and gave students problems. Research into students' misconceptions in chemistry concepts (Ali, 2012) have a common thread as the particulate nature of matter because it is the basic building block of chemistry.

Atomic theory therefore was chosen as the area of concentration for the study. A *historical perspective* to the study of the theory was adopted, with each contribution by the scientist studied and its shortcomings to explain observation clearly discussed and agreed upon with the students. Each time a theory or model for the atom failed to explain observation, it was proposed that a new and better model was in order. Atomic models from J. J. Thomson's 'plum pudding model' to the modern quantum model were discussed. Heavy dependence on technology to help students visualize the abstract notions was the order of the day. For example, free downloadable programs on the internet like Orbital Viewer by David Manthey and CD-ROMs were used to help students with the models in use. The classroom environment was also made very conducive for learning by encouraging discussion and freedom of expression. With each year that passed, adjustments were made to the materials presented based on how students responded to them.

In this study, both self study (Faikhamia & Clarke, 2013) and

exploratory case study (Koosimile & Suping, 2011) methods were used. The self study stems from the fact that the researcher also studied himself and reflected on his practice with a view to account for the changes that were occurring on the students' conceptions of atomic theory. The exploratory aspects came from the fact that though efforts were made to targets students' conceptions, it was not immediately clear from the beginning what the outcome of the treatment would be. Changes were made in the presentation of materials both within the semester as well as from year to year.

Ethical concerns were considered too. The researcher taught within the confines of the normal semester and any innovations made had to take into account the time limitations imposed by the semester as well as the fact that the students had other courses to worry about in their program of study. Nonetheless, as Koosimile and Suping (2011, p. 461) put it "...the fact that the research was integral to the normal teaching role meant that the students' consent to taking part in the study did not preclude their right to take the course without fear, intimidation or inflated expectations of rewards". This, more so in this course due to the environment, was purposefully cultivated to encourage participation by all.

Inductive analysis of data (Koosimile and Suping, 2011) and consideration of students' performance through the years led to the findings discussed in the next section.

Findings and discussions

The findings of the study are presented here according to the themes that emerged from the classroom interactions and analyses. Since the researcher was also the subject of study, reflections on one's practice are intertwined with the findings and presented simultaneously.

Partnerships in learning produce better returns

Rowell (1990, p. 108), concluded in her chapter on encouraging participation in the teaching and learning interaction that:

The study also suggests that there may be much to be gained by giving considerable attention in in-service programmes to the study of modes of classroom interaction which foster cognitive

development ... students participation for the sake of participation tends to leave the development of ideas and links between ideas to chance. In-service sessions could be tied to subject specific elaboration of recognized methods for improving the quality of communications with a view to enhancing the construction of meaning. Such examination of classroom interaction is likely to be much more valuable to teachers with two or three years of classroom experience than to pre-service teachers.

Thus, the in-service teachers provided an ideal cohort for the intervention. Brockett (1991) discusses the notion of partnership in the learning and teaching situation. This notion perceives students, especially in-service teachers, first as partners and not subordinates in the teaching and learning situation. In the cohorts that were studied, the age differences between in-service teachers and the researcher's were small, making it easier for the students to interact with the instructor. The more they were involved and engaged in the interaction, the more they developed a sense of ownership of what they were learning and the greater the desire to want to learn it. Botswana schools across the board portray teaching as:

... predominantly authoritarian and teacher-centred, and learning as passive and based on recall ... The development of concepts, attitudes, communication, and manipulative skills ... appear to be secondary to, and separated from, success in the Junior Certificate Examination (Rowell, 1990, p. 88).

This observation, despite having been made in the 1990s, is still characteristic of typical Botswana classroom. Importantly, one effective way to work with in-service teachers using PCK was that the approach was not just interested in mastery of content only, but also in ascertaining that the students see the benefit of grasping the concepts.

It must be borne in mind though that it was not easy to bring the students to freely participate in class and have a sense of ownership of what they were learning. This difficulty arises from what Tabulawa (2013) calls the oppressive African culture that dictates the teacher-

centred pedagogy so prevalent in many Botswana and African classrooms. Discussing this pedagogy, Tabulawa (2013, p. 92) laments that its “salient aspects of social structure are structures of domination and subordination which govern interpersonal relations and practices in the African context”. Familiarization therefore has to be negotiated very carefully.

The fact that the researcher was also the instructor could have jeopardized the environment that was generated by the mutual symbiotic relationships that were generated. In the classes taught by the researcher, such relationships were produced and in fact students continued to seek help from the researcher long after he had finished teaching them. This can be explained in one way; that the students felt or at least believed that the researcher could help them understand chemistry problems better. In fact they were of that opinion as evidenced by comments of one participant, Boitshwarelo (pseudo name), after they had started taking courses from the Faculty of Science:

Sir; that side we move very fast and there are no explanations made, just notes written on the board. They don't care whether you understand or not. The tests do not even cover what was taught in class [Boitshwarelo, (pseudo name) 2006 cohort].

Boitshwarelo was not alone in this seemingly hopeless scenario. Thato (pseudo name) wondered why they had to transfer to the Faculty of Science when they could just take all their courses with DMSE, a view opposed by some staff members in the department. The staff members argue that they are not trained to teach content, but methods courses. No consensus has been reached as to what the best practice would be.

Experience aids expertise

The second dimension is that since the in-service students knew the situations prevailing in the field, they were better placed to appreciate teaching practices that were likely to benefit them in class. Consistently throughout the years, the in-service teachers I have worked with have shown more commitment towards work and more positive attitudes than their pre-service counterparts. This positive disposition to success

has been attributed to mainly maturity on the part of the in-service teachers.

Asked what orbitals were in one of the classes, in-service students struggled to have a sense of what orbital are and even whether or not they had any significance beyond representing imaginary spaces occupied by electrons in an atom. This question sought an understanding of the atomic model beyond just recall in the in-service teachers. This has been referred to as *professional artistry* (Brockett, 1991), being the level of competency that allows for unprecedented flexibility in going about the professional teachers' role. Loucks-Horsley et al (1998) describe the same concept as *immersion in inquiry into science or mathematics* based on the assumption that teachers, in-service teachers in particular, during training, should be engaged in similar learning situations as they would encounter in their own classrooms.

Studies (Ali, 2012) found that students have huge gaps in understanding fundamental concepts in science and as a result are unable to engage in in-depth learning of advanced level content. Whilst this study made reference to high school chemistry students, the same can be extrapolated to in-service teachers. There were certain key concepts in chemistry that did not seem to have been well developed in the conceptual frameworks of the students, causing doubts as to the development of their understanding of the concepts.

Professional preparation of teachers versus content professional development

Changes in the teaching fraternity combined with the challenges of keeping up with professionalism are factors that make it necessary to revisit professional preparation of science teachers in the secondary schools of Botswana. Any science teacher who is dedicated to teach in a manner that makes some difference has to undergo relevant teacher preparation. However, the situation now is that at a tertiary level in Botswana, science content is still taught by science content professionals who have not been taught how to teach.

Whilst this arrangement has worked in time past, it is lacking since it

fails to ground student teachers with the necessary PCK. The key to attracting and sustaining students' interest in learning science is the ability to problematise and make relevant the intricacies of the subject. In the case of atomic structure, there is need for a better model of the atom, at least for high school chemistry. This is due to the fact that the "electronic structure of an atom and the orientation of orbitals within an atom are difficult for introductory chemistry students to envision" (Birk & Abbassian, 1996, p.636). The topic is also usually presented in "the context of the rather abstract and unfamiliar ideas of quantum mechanics" (Gillespie, Spencer & Moog, 1996, p. 617). Both of these ideas are out of reach of most high school students.

This is not an isolated incident. Chemistry education is plagued by topics that are challenging. Schwille and Dembélé (2007) discuss what they call the continuum of teacher learning. They describe teacher learning as the time period from when the teacher was a pre-scholar to the time throughout his/her teaching career. One of their astonishing findings was that teachers teach the same way they were taught. All efforts by teacher educators to bring change and reform are futile as teachers quickly upon graduation revert to teaching the way they were taught. This is not to deny the efforts made by some teachers as observed by Ali (2012). However, there are a number of indications pointing to the fact that teachers imitate their teachers. Some teachers imitate, including mannerisms, the teachers who taught them the subjects they end up teaching. Some even go to the extent of using the same set of notes that their teachers gave them when they were students.

Whereas teaching-as-taught may be beneficial in certain quarters like in cases where the teacher being imitated was a good exemplary practitioner, it is problematic on two fronts. On one end, it disregards the simple notion that teacher education is a dynamic area with changes to reflect current thinking. Secondly, today's students need new ways of reaching them; often looking for quick fixes and results with minimum effort. This cannot be ignored.

Observations

The critical question for teacher training and development is 'how do we as teacher educators empower teachers to teach complex topics like the

atomic theory?' This paper attempted to address the atomic model issue and the author's attempt to bring awareness to different cohorts of chemistry teachers during in-service courses between 2005 and 2010. All teachers had a diploma qualification and a minimum of 10 years experience teaching at the junior secondary level.

Gillespie et al. (1996) published a series that they called 'Demystifying Introductory Chemistry' in which they gave justifications for teaching the atomic structure differently than it is usually taught. They suggested that the quantum mechanical treatment should not be the basis for teaching the atomic structure at introductory level. Cognizant of problems posed by treating the topic in a more traditional manner, they suggest instead that such concepts as ionization energy, electronegativity, bond polarity, and partial charges should be used.

In trying to help student teachers understand the atomic theory, the author resorted to using the *historical development of the theory*. The premise on which this approach was based was that some of the problems that teachers face in teaching some difficult chemistry concepts are due to the teachers themselves being conceptually challenged by the same topics. It was believed therefore that teachers needed to understand the topic thoroughly in order for them to be able to teach it successfully.

The realization that there is need to attend to pre-service as well as in-service students' PCK has been around for some time now. Different authors have looked at teachers' PCK and factors that can be addressed to develop this construct (van Driel, Verlop & de Vos, 1998; Dachler & Shinohara, 2001; van Driel, de Jong & Verlop, 2002). There have also been attempts to capture and document PCK as a construct with a view to disseminating it (Loughran, Milroy, Berry, Gunstone, & Mulhall, 2001).

Since teaching experience plays a vital role in the development of PCK, in-service teachers are better placed for this kind of training or intervention. This does not mean that pre-service student teachers would not benefit from such an intervention. Usually in-service teachers' with diploma qualifications have inadequate subject matter.

Addressing this lack in a manner that encourages the development of PCK gives them the necessary skills to teach confidently.

The program followed in this study was made successful by a number of factors; there were very few students, all with very similar experiences and levels of ability for the most part. Success here is measured in terms of levels of proficiency demonstrated by the students after completion of the course. The small number allowed for individual attention both in class as well as outside class during consultations. The challenge with chemistry is that it often is a very developmental area of study. Proper understanding of topics helps with the understanding of ones that follow. For example, the atomic theory covered in this study allowed students to relate well with all the other topics which were treated subsequent to it.

This model is proposed as a viable model for in-service activities especially in the developing world. It is in the developing world where a large proportion of the teaching staff is either not qualified or possesses inadequate qualifications. This scenario is pronounced in the science and mathematics areas. Addressing these teachers' content knowledge as well as their PCK could go a long way in helping to improve science education in general. It has amazed me each time I have been involved in in-service workshops for chemistry teachers at high school level (teachers who have a minimum of a bachelor's degree in chemistry) how arguments break out on concepts that you would think are very basic to chemistry. The latest workshop in April 2008 provoked an argument about why soaps are basic and whether or not an acidic soap could ever be made.

Recommendations

Based on the study, it is recommended therefore that:

- ✓ The debate about the teaching of content should be looked into with a view to prepare chemistry teachers who can tussle with and overcome the emerging challenges of teaching science. One compromise position may be to have all education students take their content up to second year level in the faculty of education in their respective departments. This has both human and other

- ✧ resource implication. The students could then do their third and final years in the faculties of science. Challenges abound in set ups where students finish their undergraduate degrees before enrolling for teacher preparation programs, equivalence of post graduate diploma in Education (PGDE) and Masters of Education (M. Ed.) in other institutions. The main arguments against this training is that the trainee teachers do not spend enough time in education courses and as a result are half baked by the time they graduate after one (1) year. Most such programs are year long.
- ✧ The other more salient issue has to do with the optimum qualification for a chemistry teacher or a science teacher in general, to be able to effectively teach at the secondary school level. The practice in Botswana is to train and upgrade teachers to bachelor's degree level. The question still remains as to whether this is enough. Would student results change if these teachers were trained to Master's degree level? Would they be equipped and confident enough at this level to be able to face the challenges of teaching science?
- ✧ Thirdly and lastly, what should in-service teacher preparation entail? What should be emphasized during this type of training? Should the students be put through the full rigor of chemistry learning that the pre-service teacher trainees undergo or should they be put through tailor made programs that are light on content? Don't tailor-made programs water down standards and take us back to where we started? Would students who have gone through these make shift programs be paid the same as the conventional students? Do they have the same qualification?

These debates rage on in *corridor talk* without any empirical or systemic research done to seek answers. These and many other questions have to be answered.

Conclusion

Teaching is a very difficult task. Teaching science in general is a challenge. Teaching chemistry, in particular, is difficult. Others have sought ways around problems that plague chemistry teaching as

opposed to addressing them head-on. Different authors have many suggestions as to what the cause of the problems with electronic configuration teaching is at lower level chemistry. Many have suggested the way quantum chemistry is taught, some have even challenged the correctness and legitimacy of the Schrödinger equations in elementary chemistry and even chemistry in general. The challenge in all this will be to develop an atomic model or a sequence of models for the atom that do not seem contradictory as students progress from one level of chemistry to another. Or even better still develop a system of teaching atomic theory that would allow teachers to be free to look at the many permutations of discussing the topic.

The training of teachers seems to be getting eroded with time. Could the mass production of teachers due to the expansion of the education system in the Botswana be to blame for this erosion? It is interesting to note that the in-service teachers themselves had a lot of misconceptions that surfaced as the discussions went on. Could it be that we are asking teachers to teach concepts that they have problems with themselves? These and many more questions still have to be unravelled.

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